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Final Technical Report

Research Title: Effective Behavior of Composite Materials

Principal Investigator: George C. Papanicolaou

Period of Contract: August 1, 1979 to July 31, 1980

Abstract:

The following four problems have been analyzed in detail. First, the effective heat removal rate for an insulating screen with many small holes has been computed. Second, the motion of a particle in a random force field has been analyzed. This is a simplified model for the study of conductivity of a solid with impurities where a high energy conduction electron is modelled by a classical particle and the impurities by a random force field. Third, non-linear effects in the calculation of effective dielectric constants of composites (periodic and random) have been calculated. Fourth, we have analyzed, following Zakharov and Synakh (JETP 41 (1975) p. 465), the nature of the self-focusing singularity of a nonlinear beam in three dimensions.

1. Research Objectives and Statement of Work

My research objectives and work are as follows:

(i) Calculation of properties of boundaries and interfaces of composite materials.

(ii) Wave propagation, heat conduction and other transport or dynamic effects in materials with amorphous or random structure and their effective macroscopic description.

(iii) Linear and nonlinear electromagnetic effects in composites.

2. Status of Research Effort

The results of the research carried out can be described as follows:

(i) In [1] we show by somewhat intricate probabilistic methods that diffusion through a perforated insulating screen can be described asymptotically by macroscopic surface heat removal rate. This work is closely patterned after our paper [1] of last year (1978-79) which dealt with bulk heat removal rates (last year's paper is published by Springer Verlag in a volume edited by V. Balakrishnan).

(ii) In [2] we analyzed in detail the asymptotic behavior of the motion of a particle in a random force field. This is a general mathematical result (quite complicated in its details) that has many diverse implications (see the survey by H. Spohn, Rev. Med. Phys. 1980) and in particular it can serve to some extent in the understanding of conductivity in a solid with impurities. The quantum mechanical version of what we did in [2] has been treated (by Spohn, for example) but there are still many questions of interest that have not been answered.

(iii) In [3] we carried out the familiar homogenization process (see Bensoussan-Lions-Papanicolaou, Asymptotic analysis for period structures, North Holland 1978) for some nonlinear electromagnetic problems. A number of important questions have been left open here. In particular, can one find the nonlinear analog of the Clausius-Mossotti formula? We intend to look at this in detail and to carry out some numerical experiments.

(iv) In [4] with M. Weinstein (who is writing a Ph.D. thesis on thermal blooming and nonlinear beams) we analyzed the above-mentioned work of Zakharov and Synakh in more substantial detail and tied this work to more familiar asymptotic methods of the geometrical optics form. We are now attempting to do the same to non-axially symmetric beams.

3. Written Publications

- [1] Diffusion near a perforated surface, to be published in the SIAM J. on Applied Mathematics (joint work with E. Orlandi, R. Figari and S.R.S. Varadhan) (paper in final stages of preparation).
- [2] Stochastic Acceleration (galley proofs enclosed), to appear in Communications in Math. Physics (with Harry Kesten).
- [3] Electromagnetic problems in composite materials in linear and nonlinear regimes, published in a collection of papers edited by P. Ushlenghi by North Holland (paper enclosed).
- [4] On the nature of the self-focusing singularity (in preparation, joint work with M. Weinstein).

4. Personnel Associated with Research Effort

Michael Weinstein is continuing with his thesis work at present. He expects his degree in June 1981.

Enza Orlandi has been visiting with a fellowship from the Italian National Science Foundation, as has been Rodolfo Figari.

5. Interactions

During the contract period I was invited to lecture at several meetings and institutions. Some of them are:

Paris, France, IRIA (Dec. 1979); Heidelberg, Germany (July 1980);
 City Univ. of New York, Department of Physics; Case Western Reserve
 University Centennial; Harvard University; Virginia Polytechnic
 and State University; Schlumberger Inc.; etc.

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